Electronic Supplementary Material (ESM)

On the Information Physics of Primes: Foundations of the Mersenne Chain Reactor

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S1 Algorithmic Implementation: Generalized MCR Dynamics for Any Prime p

To ensure absolute reproducibility and to demonstrate the universality of the Mersenne Chain Reactor (MCR) across any prime dimension p, we provide the generalized algorithmic implementation.

This Python script rigorously simulates the spatial evolution of the reactor's matrices. It perfectly mimics the deterministic physical laws described in the main text, without utilizing any arithmetic division or standard factorization algorithms.

Crucial Algorithmic Note (The Parity Trap): The physical operator $\hat{\sigma}$ evaluates the spatial topology based strictly on the *Pump Time* $(t-1)$, not the target temporal horizon (t). The code explicitly defines `pump_time = t - 1` to enforce the physical Shift/Hold parity rule reliably for any scaling factor.

```
def simulate_mcr(p):
    """
    Simulates the deterministic Information Physics of the MCR for
 any p.
    The critical temporal horizon is Tc = 2^(p-1).
    """
    Tc = 2**(p - 1)

    # Dictionary to store the spatial history states (Psi)
    Psi = {}

    # ---------------------------------------
    # Physical Initialization
```

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```
# ----------------------------------------
# Psi(0): Pre-history state
Psi[0] = [0] * p
Psi[0][1] = 1

# Psi(1): Initial ignition state
Psi[1] = [0] * p
Psi[1][0] = 1

# ----------------------------------------
# Deterministic Physical Operators
# ----------------------------------------
def shift_right(state):
"""Cyclic rightward shift of the spatial matrix."""
return [state[-1]] + state[:-1]

def avalanche(state):
"""
Instantaneous discharge of chambers reaching capacity >= 2.
Propagates a +1 signal strictly to the rightmost adjacent chamber.
"""
res = list(state)
while any(chamber >= 2 for chamber in res):
for i in range(p):
if res[i] >= 2:
res[i] -= 2
res[(i + 1) % p] += 1
return res

# ----------------------------------------
# Temporal Evolution (The Core Reactor Loop)
# ----------------------------------------
for t in range(2, Tc + 1):

# 1. The Pump Parity Rule (Time Trap Avoided)
pump_time = t - 1

if pump_time % 2 != 0:
# ODD pump time triggers kinetic Shift
operator_state = shift_right(Psi[t-1])
else:
# EVEN pump time triggers static Hold
operator_state = list(Psi[t-1])

# 2. Superposition Principle
super_state = [operator_state[i] + Psi[t-2][i] for i in range(p)]
```

```
        # 3. Avalanche Cascade Dynamics
        final_state = avalanche(super_state)

        # Record the stable spatial topology for time t
        Psi[t] = final_state

        # ----------------------------------------
        # Saturation Verification
        # ----------------------------------------
        print(f"--- MCR Results for p = {p} ---")
        print(f"Critical Horizon (Tc): {Tc}")
        print(f"Final Spatial Topology at t={Tc}: {Psi[Tc]}")

        if all(chamber == 1 for chamber in Psi[Tc]):
        print("STATUS: Total Spatial Saturation Achieved! (Perfect Fit)")
        print(f"CONCLUSION: M_{p} is strictly PRIME.")
        else:
        print("STATUS: Voids Detected.")
        print(f"CONCLUSION: M_{p} is COMPOSITE.")

        # Example Execution
        simulate_mcr(7)
```

Listing 1: Python implementation of the generalized Mersenne Chain Reactor (MCR) to trace absolute spatial saturation for any prime p.

This algorithm provides a direct mathematical translation of the Information Physics framework. When executed for $p = 5$ or $p = 7$, it perfectly reproduces the comprehensive, collision-by-collision traces documented in the preceding supplementary tables.

S2 Absolute Determinism: The Unabridged M_7 Saturation Trace

This supplementary document provides the exhaustive, step-by-step physical trace of the Mersenne Chain Reactor (MCR) for the prime candidate M_7 ($p = 7$). The critical temporal horizon required to definitively prove primality through absolute spatial saturation is $T_c = 2^{p-1} = 64$.

Because of the extensive nature of this trace, it is presented here in its entirety to allow for rigorous verification of the underlying Information Physics rules. We strictly apply the core physical laws of the reactor at every discrete time step t:

1. **The Parity Pump Rule (The Time Trap):** The physical operator $\hat{\sigma}$ is strictly governed by the *Pump Time* $(t - 1)$, not the target time t.

    - If $(t - 1)$ is an **Odd** integer, the reactor triggers a rightward **Shift**.
    - If $(t - 1)$ is an **Even** integer, the reactor maintains a static **Hold**.

2. **Superposition:** The resulting operator state is superimposed onto the pre-history state $\Psi(t-2)$.

3. **Avalanche Dynamics:** Any chamber exceeding capacity (value of 2) instantaneously discharges, propagating a +1 signal cyclically to the right.

Table S1 meticulously records all 64 deterministic steps. As observed at exactly $t = 64$, the wave matrices seamlessly synchronize in a “Perfect Fit” without any collisions, achieving the unbroken $[1, 1, 1, 1, 1, 1, 1]$ topologythe absolute physical proof of primality.

Table S1: **The Deterministic Trace of the MCR for M_7 ($p = 7$).** Tracking parity pump operations (Shift/Hold) and superpositions up to $T_c = 64$.

t	**Pump $t-1$**	**Physical Operations & Avalanche Result**
2	1 (Shift)	$\hat{\sigma} \to [0, 1, 0, 0, 0, 0, 0]$ $+\Psi \to [0, 1, 0, 0, 0, 0, 0]$ Result $\to [\mathbf{0}, \mathbf{0}, \mathbf{1}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}]$
3	2 (Hold)	$\hat{\sigma} \to [0, 0, 1, 0, 0, 0, 0]$ $+\Psi \to [1, 0, 0, 0, 0, 0, 0]$ Result $\to [\mathbf{1}, \mathbf{0}, \mathbf{1}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}]$
4	3 (Shift)	$\hat{\sigma} \to [0, 1, 0, 1, 0, 0, 0]$ $+\Psi \to [0, 0, 1, 0, 0, 0, 0]$ Result $\to [\mathbf{0}, \mathbf{1}, \mathbf{1}, \mathbf{1}, \mathbf{0}, \mathbf{0}, \mathbf{0}]$
5	4 (Hold)	$\hat{\sigma} \to [0, 1, 1, 1, 0, 0, 0]$ $+\Psi \to [1, 0, 1, 0, 0, 0, 0]$ Result $\to [\mathbf{1}, \mathbf{1}, \mathbf{0}, \mathbf{0}, \mathbf{1}, \mathbf{0}, \mathbf{0}]$
6	5 (Shift)	$\hat{\sigma} \to [0, 1, 1, 0, 0, 1, 0]$ $+\Psi \to [0, 1, 1, 1, 0, 0, 0]$ Result $\to [\mathbf{0}, \mathbf{0}, \mathbf{1}, \mathbf{0}, \mathbf{1}, \mathbf{1}, \mathbf{0}]$
7	6 (Hold)	$\hat{\sigma} \to [0, 0, 1, 0, 1, 1, 0]$ $+\Psi \to [1, 1, 0, 0, 1, 0, 0]$ Result $\to [\mathbf{1}, \mathbf{1}, \mathbf{1}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{1}]$
8	7 (Shift)	$\hat{\sigma} \to [1, 1, 1, 1, 0, 0, 0]$ $+\Psi \to [0, 0, 1, 0, 1, 1, 0]$ Result $\to [\mathbf{1}, \mathbf{1}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{0}, \mathbf{1}]$

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Table S1 – continued from previous page

t	**Pump $t-1$**	**Physical Operations & Avalanche Result**
9	8 (Hold)	$\hat{\sigma} \to [1,1,0,0,0,0,1]$ $+\Psi \to [1,1,1,0,0,0,1]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0}]$
10	9 (Shift)	$\hat{\sigma} \to [0,1,1,0,1,0,0]$ $+\Psi \to [1,1,0,0,0,0,1]$ Result $\to [\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1}]$
11	10 (Hold)	$\hat{\sigma} \to [1,0,0,1,1,0,1]$ $+\Psi \to [1,1,0,1,0,0,0]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1}]$
12	11 (Shift)	$\hat{\sigma} \to [1,0,0,1,0,0,1]$ $+\Psi \to [1,0,0,1,1,0,1]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0}]$
13	12 (Hold)	$\hat{\sigma} \to [1,1,0,0,0,1,0]$ $+\Psi \to [0,0,1,0,0,1,1]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0}]$
14	13 (Shift)	$\hat{\sigma} \to [0,0,0,0,1,0,0]$ $+\Psi \to [1,1,0,0,0,1,0]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0}]$
15	14 (Hold)	$\hat{\sigma} \to [1,1,0,0,1,1,0]$ $+\Psi \to [0,0,0,1,0,0,0]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0}]$
16	15 (Shift)	$\hat{\sigma} \to [0,1,1,0,1,1,1]$ $+\Psi \to [1,1,0,0,1,1,0]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0}]$
17	16 (Hold)	$\hat{\sigma} \to [0,1,0,1,0,1,0]$ $+\Psi \to [1,1,0,1,1,1,0]$ Result $\to [\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1}]$
18	17 (Shift)	$\hat{\sigma} \to [1,1,0,1,0,0,1]$ $+\Psi \to [0,1,0,1,0,1,0]$ Result $\to [\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1}]$

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Table S1 – continued from previous page

t	**Pump** $t-1$	**Physical Operations & Avalanche Result**
19	18 (Hold)	$\hat{\sigma} \to [1,0,1,0,1,1,1]$ $+\Psi \to [1,0,1,0,0,1,1]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1}]$
20	19 (Shift)	$\hat{\sigma} \to [1,1,1,0,1,1,0]$ $+\Psi \to [1,0,1,0,1,1,1]$ Result $\to [\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0}]$
21	20 (Hold)	$\hat{\sigma} \to [1,0,1,1,0,1,0]$ $+\Psi \to [1,1,0,1,1,0,1]$ Result $\to [\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0}]$
22	21 (Shift)	$\hat{\sigma} \to [0,1,0,0,1,0,0]$ $+\Psi \to [1,0,1,1,0,1,0]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0}]$
23	22 (Hold)	$\hat{\sigma} \to [1,1,1,1,1,1,0]$ $+\Psi \to [1,0,0,1,0,0,0]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1}]$
24	23 (Shift)	$\hat{\sigma} \to [1,0,0,0,1,0,0]$ $+\Psi \to [1,1,1,1,1,1,0]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1}]$
25	24 (Hold)	$\hat{\sigma} \to [0,0,0,0,1,0,1]$ $+\Psi \to [0,0,0,1,0,0,1]$ Result $\to [\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0}]$
26	25 (Shift)	$\hat{\sigma} \to [0,1,0,0,1,1,0]$ $+\Psi \to [0,0,0,0,1,0,1]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0}]$
27	26 (Hold)	$\hat{\sigma} \to [1,1,0,0,0,0,0]$ $+\Psi \to [1,0,0,1,1,0,0]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0}]$
28	27 (Shift)	$\hat{\sigma} \to [0,0,0,1,1,1,0]$ $+\Psi \to [1,1,0,0,0,0,0]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0}]$

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t	**Pump** $t-1$	**Physical Operations & Avalanche Result**
29	28 (Hold)	$\hat{\sigma} \to [1,1,0,1,1,1,0]$ $+\Psi \to [0,0,1,1,1,0,0]$ Result $\to$ $[\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1}]$
30	29 (Shift)	$\hat{\sigma} \to [1,1,1,1,0,1,0]$ $+\Psi \to [1,1,0,1,1,1,0]$ Result $\to$ $[\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1}]$
31	30 (Hold)	$\hat{\sigma} \to [0,1,0,1,0,1,1]$ $+\Psi \to [1,1,1,0,1,0,1]$ Result $\to$ $[\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{1}]$
32	31 (Shift)	$\hat{\sigma} \to [1,0,1,0,0,0,0]$ $+\Psi \to [0,1,0,1,0,1,1]$ Result $\to$ $[\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1}]$
33	32 (Hold)	$\hat{\sigma} \to [1,1,1,1,0,1,1]$ $+\Psi \to [0,1,0,0,0,0,1]$ Result $\to$ $[\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0}]$
34	33 (Shift)	$\hat{\sigma} \to [0,0,1,0,0,1,1]$ $+\Psi \to [1,1,1,1,0,1,1]$ Result $\to$ $[\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1}]$
35	34 (Hold)	$\hat{\sigma} \to [0,0,1,0,1,0,1]$ $+\Psi \to [0,1,0,0,1,1,0]$ Result $\to$ $[\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0}]$
36	35 (Shift)	$\hat{\sigma} \to [0,1,1,1,0,0,0]$ $+\Psi \to [0,0,1,0,1,0,1]$ Result $\to$ $[\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1}]$
37	36 (Hold)	$\hat{\sigma} \to [0,1,0,0,0,1,1]$ $+\Psi \to [1,1,1,0,0,0,0]$ Result $\to$ $[\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1}]$
38	37 (Shift)	$\hat{\sigma} \to [1,1,0,0,1,0,1]$ $+\Psi \to [0,1,0,0,0,1,1]$ Result $\to$ $[\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0}]$

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t	**Pump** $t-1$	**Physical Operations & Avalanche Result**
39	38 (Hold)	$\hat{\sigma} \to [0,1,1,0,1,1,0]$ $+\Psi \to [1,0,0,1,0,1,1]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0}]$
40	39 (Shift)	$\hat{\sigma} \to [0,0,0,0,0,0,1]$ $+\Psi \to [0,1,1,0,1,1,0]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1}]$
41	40 (Hold)	$\hat{\sigma} \to [0,1,1,0,1,1,1]$ $+\Psi \to [0,0,0,0,0,1,0]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0}]$
42	41 (Shift)	$\hat{\sigma} \to [0,1,1,1,0,1,0]$ $+\Psi \to [0,1,1,0,1,1,1]$ Result $\to [\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0}]$
43	42 (Hold)	$\hat{\sigma} \to [1,0,1,0,0,1,0]$ $+\Psi \to [1,1,1,0,1,0,0]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0}]$
44	43 (Shift)	$\hat{\sigma} \to [0,0,0,1,1,1,1]$ $+\Psi \to [1,0,1,0,0,1,0]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0}]$
45	44 (Hold)	$\hat{\sigma} \to [0,1,1,1,1,0,0]$ $+\Psi \to [0,0,1,1,1,1,0]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1}]$
46	45 (Shift)	$\hat{\sigma} \to [1,0,1,0,1,1,1]$ $+\Psi \to [0,1,1,1,1,0,0]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1}]$
47	46 (Hold)	$\hat{\sigma} \to [1,1,0,0,1,0,1]$ $+\Psi \to [0,1,0,1,1,0,1]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0}]$
48	47 (Shift)	$\hat{\sigma} \to [0,0,1,1,1,0,1]$ $+\Psi \to [1,1,0,0,1,0,1]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0}]$

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Table S1 – continued from previous page

t	**Pump** $t-1$	**Physical Operations & Avalanche Result**
49	48 (Hold)	$\hat{\sigma} \to [0,0,0,0,1,1,0]$ $+\Psi \to [0,1,1,1,0,1,0]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1}]$
50	49 (Shift)	$\hat{\sigma} \to [1,0,1,1,1,1,0]$ $+\Psi \to [0,0,0,0,1,1,0]$ Result $\to [\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1}]$
51	50 (Hold)	$\hat{\sigma} \to [1,0,1,1,0,1,1]$ $+\Psi \to [0,1,1,1,1,0,1]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1}]$
52	51 (Shift)	$\hat{\sigma} \to [1,0,0,1,1,0,0]$ $+\Psi \to [1,0,1,1,0,1,1]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0}]$
53	52 (Hold)	$\hat{\sigma} \to [1,1,1,0,0,0,0]$ $+\Psi \to [0,0,1,1,0,0,1]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1}]$
54	53 (Shift)	$\hat{\sigma} \to [1,1,1,0,0,1,0]$ $+\Psi \to [1,1,1,0,0,0,0]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0}]$
55	54 (Hold)	$\hat{\sigma} \to [0,1,1,1,0,1,0]$ $+\Psi \to [1,1,0,0,1,0,1]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{0}]$
56	55 (Shift)	$\hat{\sigma} \to [0,0,1,0,0,0,0]$ $+\Psi \to [0,1,1,1,0,1,0]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0}]$
57	56 (Hold)	$\hat{\sigma} \to [0,1,0,0,1,1,0]$ $+\Psi \to [0,1,0,0,0,0,0]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0}]$
58	57 (Shift)	$\hat{\sigma} \to [0,0,0,1,0,1,1]$ $+\Psi \to [0,1,0,0,1,1,0]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0}]$

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Table S1 – continued from previous page

t	**Pump** $t-1$	**Physical Operations & Avalanche Result**
59	58 (Hold)	$\hat{\sigma} \to [1,1,0,1,1,0,0]$ $+\Psi \to [0,0,1,0,1,1,0]$ Result $\to [\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1}]$
60	59 (Shift)	$\hat{\sigma} \to [1,1,1,1,1,0,0]$ $+\Psi \to [1,1,0,1,1,0,0]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0}]$
61	60 (Hold)	$\hat{\sigma} \to [0,1,0,1,1,1,0]$ $+\Psi \to [1,1,1,1,0,0,1]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{0}]$
62	61 (Shift)	$\hat{\sigma} \to [0,0,1,0,1,0,0]$ $+\Psi \to [0,1,0,1,1,1,0]$ Result $\to [\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{0},\mathbf{1}]$
63	62 (Hold)	$\hat{\sigma} \to [0,1,1,1,0,0,1]$ $+\Psi \to [0,1,0,1,0,0,0]$ Result $\to [\mathbf{0},\mathbf{0},\mathbf{0},\mathbf{1},\mathbf{1},\mathbf{0},\mathbf{1}]$
64	63 (Shift)	$\hat{\sigma} \to [1,0,0,0,1,1,0]$ $+\Psi \to [0,1,1,1,0,0,1]$ **Perfect Fit** $\to [\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1},\mathbf{1}]$

S3 Scaling Horizons: The M_{13} Prime Saturation Climax ($p = 13$)

To demonstrate the structural stability and flawless scaling of the MCR over extended temporal horizons, we present the climax phase for M_{13} ($p = 13$). The critical horizon required for this dimension scales to $T_c = 2^{13-1} = 4096$. Over 4095 discrete pump operations, the physical wave continuously propagates, triggering tens of thousands of complex chain avalanches. To maintain brevity in this supplementary document, Table S2 captures only the final 3 operations. As demonstrated, at exactly $T_c = 4096$, the mathematical noise entirely vanishes, and the topology instantly locks into a Perfect Fit without a single collision. This proves that the reactor remains physically stable and deterministically accurate regardless of the operational scale.

S4 The Ultimate Falsification: M_{23} at the 4-Million Step Horizon ($p = 23$)

To conclusively prove that the MCR does not artificially force saturation and remains strictly deterministic at massive scales, we evaluate the composite anomaly M_{23} ($2^{23} - 1 = 8,388,607$).

Table S2: **The Climax of the M_{13} Trace.** The final 3 steps of a 4096-step propagation, demonstrating the abrupt and perfect spatial saturation that physically confirms primality.

t	**Pump $t-1$**	**Physical Operations & Avalanche Result**
⋮ **(4093 steps of deterministic wave propagation omitted for brevity)** ⋮		
4094	4093 (Shift)	$\hat{\sigma} \to [1,0,0,0,0,0,1,1,1,1,0,1,1]$ $+\Psi \to [0,0,0,1,0,1,0,1,1,0,1,0,0]$ Result $\to [\mathbf{0,1,0,1,0,1,1,0,1,0,0,0,0}]$
4095	4094 (Hold)	$\hat{\sigma} \to [0,1,0,1,0,1,1,0,1,0,0,0,0]$ $+\Psi \to [0,0,0,0,0,1,1,1,1,0,1,1,1]$ Result $\to [\mathbf{0,1,0,1,0,0,1,0,1,1,1,1,1}]$
4096	4095 (Shift)	$\hat{\sigma} \to [1,0,1,0,1,0,0,1,0,1,1,1,1]$ $+\Psi \to [0,1,0,1,0,1,1,0,1,0,0,0,0]$ **Perfect Fit! (Prime confirmed)** $\to [\mathbf{1,1,1,1,1,1,1,1,1,1,1,1,1}]$

The critical temporal horizon for this topology is an astronomical $T_c = 2^{23-1} = 4,194,304$. For the MCR's physical laws to hold, it must process over 4 million discrete pump cycles and mathematically *fail* to saturate at the exact climax. Table S3 reveals the final 3 operations of this massive 4-million-step propagation. As theoretically required, the wave function collapses into a fragmented topology with distinct voids, flawlessly identifying M_{23} as a composite number.

Table S3: **The Climax of the M_{23} Trace.** The final 3 operations out of 4,194,304 steps. The inevitable emergence of structural voids confirms M_{23} is composite, proving the MCR's absolute physical honesty at massive scales.

t	**Pump $t-1$**	**Physical Operations & Avalanche Result**
⋮ **(4,194,301 steps of deterministic wave propagation omitted for brevity)** ⋮		
4194302	4194301 (Shift)	$\hat{\sigma} \to [1,0,1,1,1,1,1,1,0,1,0,0,0,1,0,1,1,0,1,0,1,1,1]$ $+\Psi \to [1,0,1,0,1,0,1,0,0,1,0,0,0,1,1,1,0,0,1,1,0,1,0]$ Result $\to [\mathbf{1,1,0,0,1,0,1,0,1,0,1,0,0,0,0,1,0,1,0,0,0,1,0}]$
4194303	4194302 (Hold)	$\hat{\sigma} \to [1,1,0,0,1,0,1,0,1,0,1,0,0,0,0,1,0,1,0,0,0,1,0]$ $+\Psi \to [0,1,1,1,1,1,1,0,1,0,0,0,1,0,1,1,0,1,0,1,1,1,1]$ Result $\to [\mathbf{0,1,0,0,1,0,1,1,0,1,1,0,1,0,1,0,1,0,1,1,1,0,0}]$
4194304	4194303 (Shift)	$\hat{\sigma} \to [0,0,1,0,0,1,0,1,1,0,1,1,0,1,0,1,0,1,0,1,1,1,0]$ $+\Psi \to [1,1,0,0,1,0,1,0,1,0,1,0,0,0,0,1,0,1,0,0,0,1,0]$ **VOIDS DETECTED (Composite!)** $\to$ $[\mathbf{1,1,1,0,1,1,1,1,0,1,0,0,1,1,0,0,1,0,1,1,1,0,1}]$